INTRODUCTION

Geochemical mapping at the scale of 1:25 000, carried out at the Dąbrowa Górnicza Map Sheet M-34-63-A-b area, is the continuation of detailed serial mapping works initiated in 1996-1999 by a pilot project the Sławków Map Sheet M-34-63-B-d area of the „Detailed geochemical map of Upper Silesia" (Lis, Pasieczna, 1999). The project was ordered by the Ministry of the Environment and financed by the National Fund for Environmental Protection and Water Management.

Most of the Dąbrowa Górnicza Map Sheet area is situated within the districts of Sosnowiec city: Pogoń, Północ, Zagórze, Środula, Kazimierz, Porąbka, Zawodzie, Klimontów, Dębowa Góra, Śródmieście, Ludmiła-Staszic, Dańdówka, Bobrek, Niwka-Modrzejów and Maczki. North-eastern part of the map sheet is located within the borders of Dąbrowa Górnicza town, whereas its north-western part covers Będzin town area. The south-western part lies within the borders of Mysłowice town, and the south-eastern area is included in Jaworzno town.

The whole map area lies in the Upper Silesian Coal Basin, which is the most industrialised and urbanised region of Poland. Geological structure and occurrence of deposits of hard coal and zinc-lead ores strongly affected the natural environment of the area. Exploitation of the deposits gave rise to the development of the Upper Silesia agglomeration – the largest and the most densely populated region of Poland.

The occurrence of geological and anthropogenic anomalies of many chemical elements in soils, aqueous sediments and surface water of the region is associated with the historical and contemporary exploitation of hard coal deposits as well as mining and processing of zinc-lead ores that developed with the greatest intensity in the mid-19th century (Lis, Pasieczna, 1995a, b, 1997).

The vast majority of the map area is a heavily anthropogenically transformed industrial region. Mining, power supply and chemical industry are the main industry sectors of this area.

Some area of the sheet has also high natural values. Some woods occur in the eastern and south-eastern parts of the map sheet. In Sosnowiec and Będzin there are historic urban parks and valuable forest stand. The Castle Hill (Góra Zamkowa) is a protected landscape area in Będzin. Single nature landmarks are also scattered throughout the map sheet area.

Information on the soils, aqueous sediments and surface water quality in the surveyed area presented as geochemical maps can be useful in land use planning, assessing local plans, making decisions concerning environmental constraints, giving water-legal permits, assessing groundwater hazards and discharging duties imposed upon district governors by the Environmental Protection Law, i.e. conducting regular soil quality tests.

The internet version of the atlas is available at http://www.mapgeochem.pgi.gov.pl

A number of specialists participated in the preparation of this publication:

- **A. Pasieczna** – concept and project proposal, supervision and coordination of the research;
- **A. Dusza-Dobek, P. Dobek, T. Kołecki, W. Markowski** – sample collection;
- **A. Dusza-Dobek, P. Dobek, A. Pasieczna** – databases;
- **A. Maksymowicz, P. Pasławski, E. Włodarczyk** – leadership and coordination of analytical works;
- **M. Cichorski, J. Duszyński, Z. Prasol, K. Stojek** – mechanical preparation of samples for analyses;
- **I. Witowska** – chemical preparation of samples for analyses;
- **E. Górecka, I. Jaroń, M. Jaskólska, D. Karmasz, J. Kucharzyk, B. Kudowska, D. Lech, M. Liszewska, E. Maciołek, A. Maksymowicz, I. Wysocka** – chemical analyses;
- **W. Wolski, Z. Frankowski, P. Dobek** – grain size analyses;
- **A. Pasieczna, A. Dusza-Dobek** – statistical calculations;
- **A. Pasieczna, A. Dusza-Dobek, T. Gliwicz** – construction of geochemical maps;·
- **P. Kwecko** – geological map construction;
- **A. Pasieczna, A. Dusza-Dobek** – interpretation of results;
- **A. Dusza-Dobek, M. Głogowska, A. Bliźniuk** – characteristics of the map area;
- **M. Głogowska** – geology and mineral deposits;
- **A. Dusza-Dobek, M. Głogowska** – human impact.

CHARACTERISTICS OF THE MAP AREA

Geographical and administrative setting. The Dąbrowa Górnicza Map Sheet M-34-63-A-b area is located in the central-eastern part of the Silesian Voivodeship and covers parts of the urban districts of Sosnowiec, Dąbrowa Górnicza, Będzin, Mysłowice and Jaworzno.

The map area is located in the south of the Silesian-Cracow Upland, within a lower-order geographical unit called the Katowice Upland (Kondracki, 2000). The whole area is laid in the upper part of Vistula River drainage basin. It covers part of the drainage basin of the Czarna Przemsza River and its tributaries (Pogoria, Brynica, Bolina and Bobrek streams) and the lower part of the Biała Przemsza River drainage basin. The area of the Maczki-Bór open sand pit is an endorheic area. A number of artificial lakes developed in subsidence troughs of mining areas (in Sosnowiec). The hydrographic network has been heavily transformed by a variety of industrial activities.

Relief and geomorphology. The map sheet area is characterised by a varied topography, locally highly changed as a result of industrial activities.

The basement of the area is composed of Triassic limestones and dolomites overlying Carboniferous coal-bearing rocks. Quaternary sands cover most of the region.

Only the south-eastern extremity belongs to the Pagóry Jaworznickie hills. The Katowice Upland is subdivided into the Katowice-Bytom Plateau, Mysłowice Basin and Dąbrowa Upland (Kondracki, 2000). The highest elevation of the Katowice-Bytom Plateau (323.6 m) is located north of Zagórz town. The Bytom part of the plateau is composed of Carboniferous sandstones and shales as well as of Triassic limestones and dolomites. The characteristic feature of plateau is the indistinct erosional dissection and small denivelation of the area. The Mysłowice Basin is an erosional depression developed in Carboniferous shales and sandstones. The lowest part of this area (about 250 m a.s.l.) is located at the Brynica River mouth.

The Dabrowa Upland (composed of Palaeozoic and Quaternary rocks) occupies the north-eastern part of the map sheet. It rises to the elevation of above 300 m a.s.l.

The natural relief of the area has been significantly transformed as a result of mineral extraction and industrial development. The greatest changes in the natural environment were caused by opencast and underground extraction of hard coal, which has lasted since the early 19th century. Hard coal mining as well as metallurgy and power supply industry resulted in the formation of heaps of waste rock, metallurgical slag and other tailings, dumped in the immediate vicinity of mines, smelters and settlements. The ground surface is also heavily transformed in the areas of open sand pits (active and inactive), post-mining lakes, and post-production land.

Land use. Urban development areas of Sosnowiec, Dąbrowa Górnicza and Będzin cover 37.8% of the map sheet (Plate 2). Industrial development areas (16.8%) are located in the north and south. Non-built-up and rural areas are scattered within the entire territory.

Barren land (areas of industrial facilities, mines, landfills and waste dumps) occupies 58.7% of the map area. Forests account for 14% of the total area, allotment gardens 4.1%, and parks 2.4%. The remaining area is represented by roads and railways, water reservoirs, and urban lawns. Agricultural land covers <1% of the map sheet.

Economy. The map sheet area is a part of the historical Dąbrowa Coal District (Zagłębie Dąbrowskie), where hard coal mining as well as zinc and iron smelting have developed. Intensive development of this region started in the 19th century. The coal mining and rail network development were the crucial factors for locating iron and nonferrous metallurgy, glass smelting, engineering, electrical, motor vehicle, textile, clothing and food industries in this region (Program…, 2003a, b, 2004).

The first hard coal mine was the Reden Mine, founded in 1796 in Dąbrowa Górnicza (Długoborski, 1976). The next mines were opened in the early 19th century: Flora in Gołonóg (Dąbrowa Górnicza), Ludwik and Charlotte in Sosnowiec, Ksawery in Będzin. Until the first half of the 20th century, some of these mines had exhausted their resources, and others had expanded and merged. The following coal mines operated then: Nowa in Dąbrowa Górnicza and Nadzieja Ludwika, Hrabia Fryderyk, Ignacy, Fanny, Ludmiła (Stary Renard) and Andrzej in Sosnowiec.

After World War II the following coal mines operated in the region: Paryż, Sosnowiec, Porąbka-Klimontów and Niwka-Modrzejów that were put into liquidation in 1995–1999. The Kazimierz-Juliusz coal mine has still been operating.

Development of zinc smelting took place in the 19th century. In the period of 1815–1939, the Konstanty zinc smelter operated in Dąbrowa Górnicza (today – Reden district). The

Anna zinc smelter (later renamed to Emma) and zinc oxide manufacture started production in the Pogoń district of Sosnowiec in 1822. Another zinc smelter operated in 1822-1828 and after 1837 in Sosnowiec-Sielec. Closure of most plants in the early 20th century was the result of the economic situation and the outbreak of the World War II.

The Ksawery zinc mine and smelter was established in Będzin in the first half of the 19th century. At the same period, the zinc smelter and galvanizing shop operated also in Warpie. In 1890, the Będzin Tillmans and Oppenheim zinc-rolling mill was founded. It was later transformed into the zinc processing company (Polskie Zakłady Przemysłu Cynkowego) in Będzin (now the Będzin smelter).

Iron smelting developed at several plants. At the end of the first half of the 19th century, the Huta Bankowa steelworks was established in the area of two coal mines (Reden and Ksawery) in Dąbrowa Górnicza. The plant operates to date, producing pig iron, steel and steel products (bars, steel profiles, rings and hoops) (Przemysł..., 2008).

In 1881–1883, the Katarzyna ironworks operated in Sosnowiec. After World War II it was incorporated, along with the Sosnowiec smelter (formerly the Huldschinsky and Sons iron mill), into the Buczek steelworks. In 1883 the Puszkin smelter started production of iron in Sosnowiec-Dębowa Góra. It was renamed to the Staszic iron smelter in 1920. After World War II, drilling equipment repair works (Zakłady Naprawcze Sprzętu Wiertniczego) started operation on its premises. The iron pipe mill was founded in Sosnowiec-Dańdówka in 1902. Since after World War II, it has operated as the Cedler iron smelter (Historia..., 2008).

Many other industries have also developed throughout the map area for many years. After World War II, the Prodryn metal-electronic enterprise (Przedsiębiorstwo Wyrobów Metalowo-Elektronicznych Prodryn) and the Falind wire and rope factory operated in Sosnowiec (Radocha district). In the 1970s, the Silma small-power electric motors factory (Fabryka Silników Elektrycznych Małej Mocy) was established in Zagórze. The Politex worsted spinning mill was located in the Środula district of Sosnowiec, which has been in liquidation since 2006. The Schön (Intertex) spinning and dyeing factory and chemical plants also operated in Sosnowiec. Chemical plants, which first produced candles, later also potassium and sodium chlorate, potassium perchlorate, citric acid and sodium and calcium phosphates, have operated in the Radocha district since 1883 (Sosnowiec..., 2008).

In 1913, the regional power plant (Okręgowa Elektrownia Zagłębia Dąbrowskiego) was established in the Będzin-Małobądz district (now the Będzin Heat and Power Plant – Elektrociepłownia Będzin).

The Staszic glassworks, the only one in Poland that produced glass balloons (currently in liquidation), started production in Dąbrowa Górnicza in 1934/1935.

The following industrial enterprises operate within the map area:

– KWK Mysłowice-Wesoła hard coal mine (only its small part lies within the map area) (Katowicki Holding Węglowy, 2008),

– KWK Kazimierz-Juliusz hard coal mine (partly in liquidation),

– CTL Maczki-Bór sand opencast mine,

– BHH Mikrohuta steelworks in Dąbrowa Górnicza (formerly the Baildon steelworks) – a manufacturer of steel wire, barstocks and strips,

– Huta Bankowa steelworks (operating since 1839) – rolling mill,

– Huta Będzin non-ferrous (Cu, Zn, Sn) metal smelter,

– Huta Buczek in Sosnowiec – steelworks producing steel pipes and rolls,

– ArcelorMittal steelworks (formerly the Cedler steelworks),

- Foster Wheeler Energy Fakop (formerly Fitzner and Gamper company) in Sosnowiec-Środula, operating since 1880, producing boilers,

– Elektrociepłownia (EC) Będzin thermal-electric power station,

– Fabryka Przewodów Energetycznych in Będzin – power cable faktory,

- Spółdzielnia Niewidomych Promet in Sosnowiec-Sielec – production of electrotechnical apparatus,

– Przedsiębiorstwo Wielobranżowe Enmech – multiple company,

- Heraeus Electro-Nite company in Sosnowiec Sielec – producing sensors and probes

- Damel Electrical Machine Factory (Dąbrowska Fabryka Maszyn Elektrycznych), located in the Reden district of Dąbrowa Górnicza,

- Auto parts producers (Magneti Mirelli, Segu, Bitron, Ergom and Er-Si) in Sosnowiec,

- Silma Electric Motors – metalworking plants,

– Intertex Worsted Spinning Plant (Przędzalnia Czesankowa Intertex) in Sosnowiec-Środula,

- Koba – Organizacja Odzysku – recycling company in Dąbrowa Górnicza.

GEOLOGY AND MINERAL DEPOSITS

The geology of the map area is represented by three structural stages: Upper Palaeozoic (Carboniferous), Mesozoic (Triassic) and Cenozoic (Quaternary) (Bukowy, 1974).

The oldest **Carboniferous** rocks are the Malinowice Beds (non-coal series), attaining a thickness of approximately 800 m (Biernat, 1970). They do not expose at the surface in the map area, and are known only from boreholes and mine workings. They are overlain by a complex of sandstones and shales of the Sarnów Beds (150–200 m) included into the Namurian A, which starts the paralic series. These deposits outcrop in small patches in the north-eastern part of the map (Plate 1). They are composed of light-grey and yellow-grey fine-grained arkosic sandstones (Doktorowicz-Hrebnicki, 1935). The Sarnów Beds are overlain by the Flora Beds composed of grey shales and sandstones with coal seams of variable thickness (about 0.5–m 2.5 m). The thickness of these layers exceeds 500 m. They outcrop in the north-eastern part of the map area.

Upper Carboniferous deposits (Grodziec and Saddle beds) outcrop locally in the southern and western parts of the study area. The Grodziec Beds are represented mainly by grey shales and conglomerates containing coal seams (Biernat, Krysowska, 1956; Biernat, 1970), terminating the paralic series. They attain the thickness of 260 m and contain eight coal seams, of which few exceed 1 m thick.

The Saddle Beds are composed of 60-m thick sandstones, grey shales and conglomerates with numerous coal seams. These layers outcrop in the Dańdówka neighbourhood (Sosnowiec) and in several places near the Huta Bankowa steelworks and KWK Paryż coal mine in Dąbrowa Górnicza. They contain four 14–17 m thick coal seams, which merge into one 14–24 m thick coal seam near Dąbrowa Górnicza (Biernat, 1970).

The Ruda Beds (top Namurian) are composed of sandstones with thick coal seams, and grey shale and conglomerate interbeds. The rocks pass upwards into a series of coal-bearing mudstones containing siderite concretions. Approximately 30 coal seams have been proved in the mudstone series. The Ruda Beds occur in numerous outcrops in the southwest, northwest and centre of the map sheet. Their thickness varies from 120 to 200 m and decreases towards the east.

The Orzesze Beds (Westphalian B), up to 500 m thick, are represented by shales and sandstones with about 50 thin coal seams. Only two of the coal seams exceed 1.5 m. Characteristic feature of the Orzesze Beds are clay shale layers, a few tens of metres thick, interbedded by siderites or spherosiderites. These rocks outcrop in the belt extending from Józefów in the west, through the KWK Porąbka-Klimontów coal mine area towards the KWK Kazimierz-Juliusz coal mine in the east.

The **Triassic** succession is represented by the Buntsandstein and Muschelkalk. Outcrops of these deposits extend in the long, wide belt from Będzin to Klimontów. A small patch of these rocks occurs in the south-eastern part of the map area. Sands and red or mottled clays, included in the Lower and Middle Buntsandstein, attain the thickness varying from 20 to 40 m (Doktorowicz-Hrebnicki, 1935). They are overlain by marine carbonates, not exceeding 40 m thick. The Lower Roethian comprises mainly dolomitic marls and yellow and bluish clay shales. The Upper Roethian is composed by cavernous limestones.

The Lower Muschelkalk is represented by the Gogolin Beds (about 30–35 m thick) and overlying ore-bearing dolomites (up to 40 m thick). The Gogolin Beds at the base are composed of limestones with fragments of molluscs (*Pecten*) and crinoids (*Dadocrinus*), overlain by wavy and conglomeratic limestones. Ore-bearing dolomites do not constitute a separate stratigraphic horizon. They are considered epigenetic deposits accompanying mineralization. Dolomite outcrops occur in Będzin (west of the EC Będzin heat and power plant), near Sielec-Dańdówka (Sosnowiec) and in the south-eastern end of the map sheet. The ore-bearing dolomites contain zinc and lead ore, a common mineral deposit in the Silesia-Cracow region (Górecka 1993, 1996; Szuwarzyński, 1996).

Diplopora dolomites, 15–20 m thick, are included in the Upper Muschelkalk and outcropped in Będzin. Their characteristic feature is the considerable content of *Diplopora annulata* fossils, oncolites and detrital grains. In places, they are devoid of fossils and karstified as a result of leaching.

Quaternary deposits are represented by Pleistocene and Holocene series. Pleistocene deposits are composed of glaciofluvial clays, sands and gravels, and sandy and silty eluvial covers of the Middle Polish Glaciation. They fill topographic depressions and ancient river valleys. Thickness of these deposits range from 70 m in the Biała Przemsza River valley outside the map area (Zieliński, Lewandowski, 1990), and they vary from several to 20 m in the map sheet. The Holocene is represented by fluvial muds and lacustrine sands.

Mineral deposits. The following **hard coal** deposits occur in the map area: Paryż, Sosnowiec, Mysłowice, Niwka-Modrzejów, Porąbka-Klimontów and Kazimierz-Juliusz (Jochemczyk, Olszewska, 2002). Their extraction (except for the Kazimierz-Juliusz and Mysłowice coal deposits) has been abandoned (Przeniosło, ed., 2007). The Kazimierz-Juliusz coal mine produces coal from the strongly faulted coal seam 510 of the Upper Silesian sandstone series, attaining thickness of 21 m. Previous extraction was carried out also from the coal seams 409, 418 and 420 (Vademecum, 2009). Calorific value of the coal is 20–26 MJ/kg. It contains 2–18% of ash and 0.3–1% of sulphur (KWK Kazimierz-Juliusz, 2010). The coal is used mainly by heating and power supply sectors.

Triassic **limestone** and **marl** deposits used by lime and cement industry (Sosnowiec-Środula I and II) and occurring in the northern part of Sosnowiec (Przeniosło, ed., 1997) were mined in the 1950s and 1960s (Program..., 2003a).

Three **clay** raw material deposits for building ceramics are located in the map area. The Dąbrowa Górnicza (Carboniferous) and Radocha (Carboniferous and Quaternary) deposits are represented by clays, loam and clay shales. Their extraction has been abandoned (Program ..., 2003a, b; Przeniosło, ed., 2005). Quaternary tills of the Sosnowiec deposit have been exploited since 1872. Now, part of the excavation shall be reclaimed. Clay raw material deposits for building ceramics have little economic significance.

In the south-eastern part of the map area, there is the Quaternary Maczki-Bór deposit of filling **sands**, genetically linked with the clastic series filling the ice-marginal valley of the Biała Przemsza River. In the western part of the excavation, industrial waste is dumped.

In the 19th century, **Zn–Pb ores** were extracted in the map area. The ore was mined from the Triassic ore-bearing dolomites in the present-day Będzin–Ksawera district.

HUMAN IMPACT

Long-lasting industrial activity and heavy urbanization have strongly affected the quality of natural environment in the study area. These factors are potential sources of pollution, causing land degradation and modifications of the landscape, as well as irreversible changes in the hydrographic network.

Atmospheric air. Air pollution by emission of dust and gas is the factor that significantly influences the contamination of soils and water of natural environment. The quality of atmospheric air is dependent on emission from industrial sources, road transportation and individual furnaces. The most serious sources of the air pollution are heat and power plants (power plant of the former Cedler steelworks and municipal heat and power plant in Będzin) and the Bankowa, Będzin, Buczek and Mikrohuta steelworks.

Air pollution is also caused by plants located beyond the map area boundaries: the ArcelorMittal steelworks (formerly Huta Katowice steelworks), the Przyjaźń coking plant (Zakłady Koksownicze Przyjaźń) in Dąbrowa Górnicza, the Szopienice non-ferrous metal smelter and the Katowice Power Plant.

The source of air pollutants are periodical emissions from landfills. Among the largest industrial landfills is that located in the Maczki-Bór opencast sand mine. Odour emission takes place mostly around sewage treatment plants and municipal and industrial waste landfills.

Fuel combustion from motor vehicles (carbon oxides, hydrocarbons and lead compounds) also contributes significantly to the air pollution.

Surface water and groundwater. The quality of surface water and groundwater is affected mostly by discharges of industrial (from steelworks and manufacture of machinery) and municipal sewage, and leachates from landfills. Deterioration of surface water quality is mainly caused by discharges of saline mine waters coming from drainage of the active or closed coal mines Kazimierz-Juliusz, Porąbka-Klimontów, Sosnowiec, Mysłowice-Wesoła and Paryż. Surface waters are also polluted by sources located outside the map area. Pollution of the Biała Przemsza River water originates from industrial sewage of Zn–Pb mines (Olkusz and Pomorzany) and the Bolesław (Zakłady Górniczo-Hutnicze (ZGH) Bolesław) zinc smelter (Zakłady..., 2010). The Bobrek Stream receives sewage generated during the technological processes in the ArcelorMittal steelworks and the Zakłady Koksownicze Przyjaźń coking plant. The Bolina Stream water is contaminated by municipal and industrial sewage from the Mysłowice area, whereas the quality of the Brynica Stream water is affected by sewage from the Katowice and Bytom urban regions.

A separate group of pollutants are leachates from sewage treatment plants and municipal wastes. Unpurified municipal sewage is the source of pollution transported to the rivers, causing oxygen deficit and increased contents of organic and bacteriological contamination (Ocena…, 2007).

Several municipal and industrial sewage treatment plants operate in the study area. Among the largest ones are RPWiK Sosnowiec-Zagórze, Kazimierz, Radocha II and Porąbka in Sosnowiec. Industrial wastewater treatment plants operate at the Cedler smelter and the PW Enmech in Sosnowiec, the Będzin power plant, the Będzin smelter, and the Mikrohuta smelting works in Dąbrowa Górnicza and others.

Pollution of surface water also affect groundwater reservoirs. In the northern part of the map area there is the Carboniferous Major Groundwater Basin (MGWB) Będzin of a fissure-pore nature (Kleczkowski, 1990). The MGWB Bytom has the largest extent. It stretches from the north-western boundary of the map sheet to the Klimontów region. The aquifer is represented by fissured and karstified Triassic carbonates. Individual water-bearing horizons form a single water-bearing complex of Triassic carbonates, recharged directly in the areas of outcrops of limestones and dolomites or indirectly through Quaternary deposits (Różkowski, Siemiński, 1995; Kowalska, 1997). In the south-eastern part of the map area, there is a small fragment of the fissure-karst Triassic MGWB Chrzanów, which is exposed to areal contamination from the outcrops.

Mining activity resulted in disruption of water balance within the area of continuous drainage, lowering the groundwater table, changes in underground and surface runoff, reduction of the water reserves and water loss in wells (Wilk, 1990).

Soils. Almost the entire map sheet is the area of active mining or recently abandoned coal mines and the area of mining damages. The ground surface has been transformed by former open cast and underground mining (resulting in continuous and discontinuous deformation) (Chwastek *et al.*, 1990). Another factor influencing the pollution of the soil is the presence of numerous mining waste disposal sites (of gangue, slime, coal slurries and mine waters), smelting wastes (metallurgical slag) and opencast mines of rock materials. The major threat to the soil quality is the hazardous waste landfill located at the Sosnowiec/Dąbrowa Górnicza border (Silma company premises).

Dust emissions from industrial plants, road transportation and municipal landfills significantly contribute to the contamination of soils.

The use of mining waste to the reclamation of brownfield areas, road construction and water engineering contributes to the spread of contamination penetrating the soil profile (Skarżyńska *et al.*, 1988).

Due to highly developed industry and intensive urbanization, land used for agricultural purposes occupies a very small area in the map sheet.

MATERIALS AND METHODS

The 2005–2008 researches included studying published and archival materials, selecting sampling sites in topographic maps at the scale of 1:10 000, collecting samples, coordinate surveying at sampling sites, chemical analyses of samples, setting up field and laboratory databases, preparing a vector topographic map, statistical calculations, constructing geochemical maps and a geological map, and finally interpretation of results. The sequence of investigations is shown in Figure 1.

FIELD WORKS

Soil samples were collected at a regular grid of 250x250 m (16 samples per 1 km^2). The total number of soil sampling sites was 1332. At every site, two samples were collected from two depths: 0.0–0.3 (topsoil) and 0.8–1.0 m (subsoil). If the parent rock was found shallower in the soil profile the subsoil sample was collected at a smaller depth. Soil samples (ca. 500 g) were collected using a 60-mm hand probe, put in linen bags labelled with numbers, and pre-dried on wooden pallets at a field storage site.

Samples of aqueous sediments and surface water were collected form rivers, streams, melioration ditches, canals, settling ponds, pools and ponds. The distance between watercourse sampling sites was about 250 m. 500 g sediment samples (of possibly the finest fraction) were taken from water reservoir shores using a scoop. They were subsequently placed in 500 ml plastic containers labelled with numbers.

Surface water samples were collected at the same sites as aqueous sediment samples. Specific electrical conductivity (EC) and acidity (pH) of water were measured on site. EC was measured using conducometer with automated temperature compensation, assuming the reference temperature of 25^{o}C. Water samples were filtered on site using 0.45 μm Millipore filters and acidized with nitric acid in 30 ml bottles. The bottles were also labelled with numbers.

All the sampling sites were indicated in topographic maps at a scale of 1:10 000 and numbered. Locations of the sampling sites were defined with GPS, using a device equipped with an external antenna and a computer which can record not only coordinates but also additional information (pH and EC of water samples, data on land development and land use, type of soil and aqueous sediment). The coordinates were taken with an accuracy of ±2 – 10 m. The coordinates of soil sampling sites were put into the memory of the GPS equipment, before going out in the field, and the sites were subsequently found using the satellite positioning system. For database safety reasons, all the field data were also noted on special sampling cards (Fig. 2).

LABORATORY WORKS

Sample preparation. The soil samples were air-dried and sieved through a 2 mm nylon sieve. Each topsoil sample (0.0–0.3 m) was split into three portions: one of them was submitted for chemical analysis, the second one was analysed for grain-size and the third one was archived. Each subsoil sample (0.8–1.0 m) was sieved and split into two portions: one of them was submitted for chemical analysis and the other one was archived (Fig. 1). The soil samples for chemical analyses were pulverized in agate planetary ball mills to a grain size <0.06 mm.

Aqueous sediment samples were air-dried and then sieved through a 0.2 mm nylon sieve. The <0.2 mm fraction was divided into two portions: one of them was used for chemical analysis and the other was archived (Fig. 1).

All the archive samples are stored at the Polish Geological Institute-National Research Institute in Warsaw.

Chemical analyses were carried out at the Central Chemical Laboratory of the Polish Geological Institute-National Research Institute in Warsaw.

Soil and aqueous sediment samples were digested in aqua regia (1 g of sample to final volume of 50 ml) for 1 hour at the temperature of 95^{o}C in the aluminium heating block thermostat.

Contents of Ag, Al, As, Ba, Ca, Cd, Co, Cr, Cu, Fe, Mg, Mn, Ni, P, Pb, S, Sr, Ti, V and Zn in the soil and aqueous sediment samples were determined by an inductively coupled plasma atomic emission spectrometry (ICP-AES) method. Mercury content was measured using a cold vapour atomic absorption spectrometry (CV-AAS) method. Soil pH was measured by water extractions using a pH-meter. Organic carbon content was measured using a coulometric method. Determination of B, Ba, Ca, Cr, Fe, K, Mg, Mn, Na, P, SiO_2, SO_4, Sr, Ti and Zn in surface waters was performed by an ICP-AES method. Contents of Ag, Al, As, Cd, Cl, Co, Cu, Li, Mo, Ni, Pb, Rb, Sb, Tl and U were analysed using an inductively coupled plasma atomic mass spectrometry (ICP-MS) method. The applied analytical methods and the detection limits of measured elements are shown in Table 1.

Quality control was performed through analysis of duplicate samples (about 5% of all samples), analysis of reference materials with certified content of elements studied (2% of all samples) and analysis of laboratory control samples confirming correct instrument calibration (5% of all samples). ‘Reagent blank samples’ and ‘preparation blank samples’ were used. Purity of reagents and vessels was controlled with ‘reagent blank samples’. ‘Blank samples’ (*sea sand extra pure Merck*) were used to monitor for possible contamination introduced during the sample preparation procedure.

For the solid samples, analytical precision is ±10–15%. For the surface water samples, analytical precision is about ±10–20% (depending on the element’s concentration).

Grain size analyses of topsoils (0.0–0.3 m) samples were carried out at the Hydrogeology and Engineering Geology Laboratory of the Polish Geological Institute-National Research Institute in Warsaw, using a laser particle size analyzer. Direct use of laser method results does not allow soil classification according to pedological criteria. However, the data are very useful for interpretation of geochemical analyses.

The results of grain size analyses (recalculated to percentage ranges) are presented in the maps with regard to the following grain size classes: sand fraction 1.0–0.1 mm, silt fraction 0.1–0.02 mm and clay fraction <0.02 mm (Plates 4–6).

DATABASES AND GEOCHEMICAL MAPS CONSTRUCTION

Base topographic map. The 1:25 000 scale topographic base map was constructed using the most up-to-date *1992* coordinate system topographic map at the scale of 1:50 000, Katowice Map Sheet M-34-63-A (vector map VMap L2). The topographic map contains the following vector information layers: relief, hydrography (including dividing into rivers, streams, ditches and stagnant water reservoirs), road communication network (with road classes indicated), railway network, land development (including classification into rural, urban and industrial development), forests, industrial areas (industrial objects, mine shafts, mine excavations, mine dumps and tailing ponds).

Geological map. Geological map was constructed on the basis of Detailed Geological Map of Poland, 1:50 000, Katowice Map Sheet (Biernat, Krysowska, 1956). Individual elements of the geological map were digitized to create their vector images which were subsequently combined with the topographic base, producing a geological map at the scale of 1:25 000 (Plate 1).

Database management. Separate databases were prepared for: topsoil (0.0–0.3 m), subsoil (0.8–1.0 m), aqueous sediments and surface water.

Soil databases contain the following information: sample number, sampling site coordinates, site description (land development, land use, soil type, sampling site location – district, commune and locality), date of collection, sampler name and analytical data.

Aqueous sediment and surface water databases contain the following information: sample number, sampling site coordinates, site description (land development, land use, water body type, sediment type, sampling site location – district, commune and locality), date of collection, sampler name and analytical data.

Statistical calculations. Information from the databases were used to create subsets for statistical calculations according to different environmental criteria, e.g. concentrations of elements in soils of industrial areas, forest soils, urban soils and in aqueous sediments and water of individual water bodies, as well as for geochemical map construction. Statistical calculations were made for both whole datasets and subsets created for soils, aqueous sediments and surface water. In the case of some elements with the content lower than the detection limit value for the given analytical method, half of the detection limit value was taken. The arithmetic and geometric means, median, minimum and maximum values were calculated. These data specified for individual elements, pH and EC are shown in Tables 2–5 and presented in the geochemical maps.

Maps construction. The following maps were produced for the Dąbrowa Górnicza Sheet (Plates 2–63): land development, land use, contents of total organic carbon and grain size of topsoil (sand, silt and clay fractions); acidity of topsoil and subsoil; contents of Ag, Al, As, Ba, Ca, Cd, Co, Cr, Cu, Fe, Hg, Mg, Mn, Ni, P, Pb, S, Sr, Ti, V and Zn in topsoil, subsoil and in aqueous sediments; acidity, specific electrical conductivity and contents of Ag, Al, As, B, Ba, Ca, Cd, Cl, Co, Cu, Fe, K, Li, Mg, Mn, Mo, Na, Ni, P, Pb, Rb, Sb, SiO_2, SO_4, Sr, Ti, Tl, U and Zn in surface water; topsoil classification indicating appropriate soil use.

Land development, land use and topsoil classification indicating appropriate soil use are presented as dot maps (Plates 2, 3 and 63).

To show the distribution of grain size classes (Plates 4–6) and the contents of elements in soils, contour maps were constructed because of their clarity and legibility. The geochemical contour maps were produced using the Surfer software and the *Inverse Distance to a Power method*. The classes of contents of elements were created most often using geometric progression.

Soil acidity (Plates 7 and 8) is presented according to the soil science classification (acidic, neutral and alkaline soils).

The geochemical maps of soils were constructed using the analytical dataset created for the Dąbrowa Górnicza Sheet and the datasets of 1:25 000 scale neighbouring sheets. Thus any disagreements at the sheet borders were avoided. After interpolation the Dąbrowa Górnicza Sheet was extracted from mono-element maps and combined with the topographic base map.

The geochemical maps of aqueous sediments and surface water were elaborated separately for the Dąbrowa Górnicza Sheet area only. They were constructed as dot maps with the circle diameters corresponding to individual classes, most often according to geometric progression.

While constructing the map of soil classification indicating appropriate soil use (Plate 63), the results of geochemical analyses were referred to the permissible levels of metals, defined in the Regulation of the Ministry of the Environment (Rozporządzenie..., 2002), according to the recommendation that ’soil or land is considered polluted if the concentration of at least one substance exceeds the permissible limit value’.

Based on the contents of individual metals analysed (specified in the Rozporządzenie..., 2002), each soil sample was categorized into class A, B or C. In the case of equal permissible limit values for classes A and B (for arsenic, barium and cobalt), the soil was categorized into class A, which is more advantageous to the user and enables multifunctional land use.

For publication purposes, the geochemical maps were constructed by combining the maps into pairs: the topsoil map is presented together with the aqueous sediment map, and the subsoil map is shown with the surface water map. This method of presentation provides the possibility of direct comparison of geochemical images of various media. Taking into account the comfort of potential users, the maps (with a bar scale shown) have been printed out in a slightly smaller format (A3). This operation did not cause omitting any important details of the maps. The whole report or its individual plotter printed maps are available for those who are interested in 1:25 000 scale maps.

RESULTS

SOILS

Parent rocks of the soils are represented in this region by Carboniferous, Triassic and Quaternary deposits. They are lithologically differentiated rocks (Plate 1) that gave rise to a variety of soil types. *Rendzinas* developed on Triassic limestones and dolomites. Quaternary tills are the parent rocks of *Cambisols* and *Luvisols*. *Podzols* developed on Carboniferous sandstones and Quaternary glaciofluvial sandy deposits. Large areas are covered by *Anthrosols* (Program…, 2003a, b; 2004), locally over 2 m thick (Rzepecki, Suchanecki, 1995).

Economic activity has contributed to significant changes in soil profiles and their physicochemical properties. Degradation processes occur primarily in the areas of industrial facilities, at landfill sites and in built-up areas, close to transportation routes and in the areas of mineral extraction.

Grain size. One of the factors determining the content of chemical elements in soils is their grain size.

Soils rich in the clay fraction (<0.02 mm) and silt fraction (0.1–0.02 mm) are commonly characterized by greatest content of many elements and their low migration ability under hypergenic conditions. The standards and recommendations on permissible limits of elements in soils commonly take this soil property into account, allowing higher concentration limits for clay fraction-rich soils and lower limiting concentrations for sand fraction-rich soils (Kabata-Pendias *et al.*, 1995).

Grain size variability of analyzed soils is dependent on the parent rock lithology. The most abundant are sandy soils containing >75% of the 1.0–0.1 mm fraction, which developed on Pleistocene glaciofluvial sands and gravels, Triassic carbonates and Carboniferous sandstones. These soils are characterised by a small proportion (<10%) of the silt fraction (0.1–0.02 mm) and clay fraction (<0.02 mm). In the Maczki-Bór sand mine and in the Biała Przemsza River valley, the sand fraction content in soils exceeds 90%.

Upon the outcrops of Carboniferous shales and Pleistocene tills the soils are enriched in the silt fraction (10–20%). The largest proportion of the clay fraction (>10%) is observed in the soils developed on Carboniferous claystones and Quaternary tills between Zagórz and Józefőw in the northern part of Sosnowiec.

Acidity. Both the topsoils (0.0-0.3 m) and subsoils (0.8-1.0 m) are mostly acidic. The deeper horizon is represented by more soils of pH >8. Strongly alkaline soils are observed along the Czarna Przemsza River valley (the most industrialised region of the map sheet) and near the excavations of the Maczki-Bór sand mine. Alkalinisation of the soils may be the result of scattering dust containing calcium and magnesium compounds from industrial plants, periodic dusting from waste heaps of mines, steel mills and power plants, and dusting from excavations of Triassic limestones and dolomites extracted for local needs.

Neutral and acidic soils occur in the east of the map sheet. Both in the topsoil and subsoil horizons, acidic soils (pH <6.3) occupy less than 10% of the map area and occur mainly in forests. The lowest pH values (pH <5) were observed in the soils of forests situated to the north of the Rów Mortimerowski valley in the northern districts of Sosnowiec.

Geochemistry. Soil-forming processes and anthropogenic transformations have led to significant chemical changes of soils in relation to their parent rocks; however, the main geochemical features of the parent rocks have commonly been preserved. Distribution of many elements allows tracing the variability of geochemical background and identification of local anomalies.

The elements characterizing the bedrock lithology (geogenic elements) are aluminium, barium, calcium, cobalt, chromium, iron, magnesium, manganese, nickel, phosphorus, strontium, titanium and vanadium. The lowest contents of these elements are observed in the soils developed on Pleistocene sandy deposits covering the south-eastern part of the map area. It refers to both topsoil and subsoil. Low contents of the elements are associated with the poor chemical composition of the bedrock. The soils of the central and western parts of the map area contain higher amounts of almost all elements, which is related to their development from Triassic carbonates and Carboniferous clay shales.

The distribution pattern of the geogenic elements in subsoil is highly diversified. Soils from the depth of 0.8–1.0 m, which developed on Carboniferous outcrops are enriched in aluminium, barium, cobalt and vanadium. Increased calcium and magnesium concentrations are reported from the areas of carbonate rock.

High content of barium and strontium in soils (at both depth intervals) of the Czarna Przemsza River valley is probably related to long-lasting discharges of mine water, and EC Będzin heat and power station dust emission, originating from combustion of coal rich in these elements (Różkowska, Ptak, 1995a, b).

In the areas of industrial facilities high contents of iron (>4%) and manganese (>1600 mg/kg) were observed. The maximum concentrations of these elements were found in topsoil at the Maczki-Bór sand mine, where municipal and industrial waste landfill is located.

Soils that developed on Quaternary sandy deposits and Triassic carbonates contain the low amount of organic carbon (<3%). In soils developed on Carboniferous rocks and river muds organic carbon content varies commonly from 3 to 6% while peaty soils contain up to 43.5% of organic carbon (Table 2). Concentrations of organic carbon exceeding 24% occur in anthropogenic soils at the former KWK Paryż coal mine area (currently a coal processing plant), in reclaimed areas of the former KWK Porąbka-Klimontów coal mine, post-mining dumps of the KWK Kazimierz-Juliusz and around the sludge landfill of the KWK Mysłowice-Wesoła coal mine.

The sulphur content in soils of the map area rarely exceeds 0.160%. A topsoil sulphur anomaly (with a maximum of 6.680%) occurs at the industrial waste dump site of the Maczki-Bór sand mine excavation.

Numerous anthropogenic anomalies of many elements were noted in the areas of extraction of mineral deposits, around industrial plants, near tailings piles and landfills, and in the alluvial soils of the Czarna Przemsza River valley.

At most of the study area, the topsoils contain more than 4 mg/kg of cadmium, above 100 mg/kg of lead and above 500 mg/kg of zinc. At the depth of 0.8–1.0 m, the area of increased concentration of these elements is smaller (Table 6).

Cadmium, lead and zinc anomalies observed between Sielec, Dańdówka and Klimontów in Sosnowiec are natural in origin and associated with outcropping of ore-bearing dolomites.

Remarkable geological-anthropogenic anomalies of cadmium, lead, zinc, silver, and arsenic have been recorded in the area of the old Zn–Pb mine and zinc smelter in the Ksawera and Warpie districts of Będzin, and in the areas of zinc smelters that operated in the 19th century in the Sielec, Pogoń, Zagórze and Józefów districts of Sosnowiec. The production of these smelters was based on processing of local ore and, once the reserves ran out, of ores from the Chrzanów and Sławków regions. In the anomaly area, the high concentrations of cadmium (>32 mg/kg), lead (>1000 mg/kg) and zinc (>5000 mg/kg) were recorded at the depth of 0.8–1.0 m.

The strongest anthropogenic anomalies occur in the topsoils between the Czarna Przemsza River and Brynica River valleys. In the Radocha residential area of Sosnowiec, the soils contain more than 16 mg/kg of cadmium (up to 360 mg/kg). The lead and zinc concentrations are >100 mg/kg (locally >250 mg/kg) and >1000 mg/kg, respectively.

These soils are also enriched in silver (>2 mg/kg), mercury (>0.20 mg/kg) and arsenic (>40 mg/kg). The suspected sources of metals are discharges of wastewater from metallurgical plants located in the upstream part of the Czarna Przemsza River drainage basin (Bankowa, Będzin and Buczek steelworks and EC Będzin thermal-electric power station). The likely source of contamination is also wastewater and waste products from the Prodryn metal-electronic devices company, chemical plants and the Falind wire and rope factory (Fabryka Lin i Drutu Falind), which has operated in the Radocha district since World War II. The soils that developed on alluvial sediments in river confluence areas could be polluted with sewage during high water levels and periodic floods.

The topsoils of the Czarna Przemsza River valley around the Będzin steelworks is among the areas most polluted by silver (>2 mg/kg), arsenic (>40 mg/kg), chromium (>20 mg/kg), copper (>80 mg/kg), mercury (>0.20 mg/kg), nickel (>20 mg/kg), lead (>250 mg/kg) and zinc (>1000 mg/kg). Concentrations of these elements are associated with the activity of the smelter that produced zinc white, sheet zinc, steel sheet and zinc utensils in the late 19th century. A strong copper anomaly (with a maximum of 2500 mg/kg) is also observed in subsoil. Its occurrence may be associated with non-ferrous metals processing in the Będzin smelter, which for decades has been involved in producing copper tubes, profiles and rods.

Cadmium, lead and zinc anomalies in alluvial soils of the Biała Przemsza River valley developed as a result of transport of contaminated sediments and water from the areas of extraction, enrichment and processing of Zn–Pb ores in the Olkusz region.

Anthropogenic pollution of soil was proved in the Huta Bankowa iron smelter area. The following anomalies were found there: chromium (40 mg/kg), copper (>80 mg/kg), iron (>4%), mercury (>0.40 mg/kg), manganese (>800 mg/kg), lead (>250 mg/kg), sulphur (>0.160%) and zinc (>500 mg/kg). There are also increased contents of cobalt (>8 mg/kg), nickel (>20 mg/kg) and titanium (>250 mg/kg). Around the Mikrohuta steelworks (formerly Baildon steelworks) in Dąbrowa Górnicza much less contaminated soils occur. They are enriched only in chromium and nickel. Production of the Buczek and ArcelorMittal steelworks in Sosnowiec caused no significant contamination of soils.

Serious threat to the natural environment in the area of Sosnowiec-Zagórze is the landfill of hazardous waste located at the former electric motors factory (Silma company) and the area of inactive coal mine shafts (Józef, Ryszard and Jadwiga) of the former KWK Porąbka-Klimontów and Mortimer II coal mines. The soils there are contaminated by silver, arsenic, iron, mercury, nickel, lead, strontium, titanium and zinc. Chromium and copper anomalies were additionally noted around the landfill of the Silma company facility.

Mercury anomalies (>0.40 mg/kg) were found in the areas of the Huta Bankowa smelter, the Damel electric motor company and the Koba company (recovery of materials) in Dąbrowa Górnicza and along the Czarna Przemsza River valley (in the following areas: Huta Będzin smelter, northern Radocha district in Sosnowiec, boilers factory in Środula, Heraeus company, the manufacturer of sensors and measuring equipment in Sosnowiec).

Proportion of areas of soil contaminated by cadmium, zinc and lead is presented in Table 6. Over most of the map area (69.59%), the topsoil contains <4 mg/kg of cadmium. Lead contents of ≤100 mg/kg was found in 48.20% of the soils, whereas zinc contents of ≤500 mg/kg was found in 64.19% of the soils. The topsoils contaminated by cadmium (>16 mg/kg), lead (>500 mg/kg) and zinc (>2500 mg/kg) occupy respectively 2.03%, 3.23% and 1.95% of the map sheet area. The contaminated subsoil area is much smaller.

The heavy metal contamination of soils is a problem for the local authorities and should be discussed with respect to the appropriate land use. To fit the geochemical data to the local authorities' needs the topsoils of the Dąbrowa Górnicza Sheet were classified applying current guideline values (Table 7) established by the Polish Ministry of the Environment (Rozporządzenie…,2002). The guideline values are based on the average of particular elements in soils for Poland as a whole and also on the assessment if the content of a particular element may have negative influence on the ecosystem or on human health. Guideline values are applied for three-level scale: A (protected areas), B (agricultural, forest and residential areas) and C (industrial areas).

The total classification was calculated using the rule that the sample is classified to a particular soil use group if the content of at least one element exceeded the permissible limit value. With respect to concentrations of metals, 6.76% of the topsoils were included into group A, 26.05% of the topsoils were classified into group B and 67.19% of the topsoils into group C (Table 7). The only soils meeting requirements of multipurpose use are those categorized into classes A and B. Class C soils occur in industrial areas of the northern, western and central parts of the map sheet (Plate 63). The map shows the recommended land use according to guidelines provided in Rozporządzenie... (2002). Much of the soils are currently improperly used and require monitoring or reclamation. Concentrations of metals in soils of some forest, agricultural, grassland and garden areas are so high that the land should be used for industrial purposes.

AQUEOUS SEDIMENTS

The analysed sediments were collected from the Czarna Przemsza River (and its tributaries: Pogoria, Potok Zagórski, Brynica and Bolina), the Biała Przemsza River and the Bobrek Stream (and its tributary Rów Mortimerowski Stream).

Czarna Przemsza River and its catchment. The most industrialized and urbanized area of the map sheet is located in the Czarna Przemsza River drainage basin, in which all watercourses (except for a small section of the Potok Zagórski Stream) flow in engineered river channels.

The average contents of aluminium, silver, arsenic, barium, cadmium, cobalt, magnesium, nickel, lead, sulphur, strontium, titanium, vanadium and zinc in alluvial sediments of the Czarna Przemsza River drainage basin (Table 4) are close to geochemical background values for aqueous sediments of the Silesian-Cracow region.

Alluvial sediments of the Czarna Przemsza and Pogoria rivers contain elevated amounts of chromium (20-50 mg/kg), iron (1.50-3.00%) and mercury (0.40-2.50 mg/kg), and, in the upstream part the catchment - of manganese (1000-2000 mg/kg). The sediments are locally enriched in silver, nickel and vanadium. The source of the metals are wastewater discharges from the steelworks (Bankowa, Będzin and Buczek) and the EC Będzin thermal-electric power station. Aqueous sediments of a canal draining the area of the Huta Bankowa steelworks contain high amounts of cadmium (72 mg/kg), chromium (82 mg/kg), iron (18.00%), mercury (2.08 mg/kg), lead (3600 mg/kg) and zinc (11 250 mg/kg).

Strongly polluted aqueous sediments were found in the unnamed watercourse (recharging the Potok Zagórski Stream in the Józefów area). They show high concentrations of barium (up to 338 mg/kg), calcium (>20%), cobalt (up to 105 mg/kg), iron (up to 8.53%), manganese (up to 22 000 mg/kg), nickel (up to 112 mg/kg), strontium (up to 607 mg/kg) and zinc (up to 10 900 mg/kg). Anomalies of these elements were also found in soils of the stream drainage basin. The source of the contamination is probably the old landfill located in the post-mining excavation. The landfill is reclaimed and used as an allotment garden area.

Alluvial sediments of the Brynica, Bolina and Przemsza rivers (downstream of the discharge site of wastewater from the ArcelorMittal steelworks) contain high concentrations of cadmium, chromium, copper, iron, mercury and sulphur. The Bolina River aqueous sediments are characterized by a particularly high content of copper (1200–1800 mg/kg). The source of the contamination in this part of the drainage basin are discharges of industrial and municipal wastewater. The Brynica River transports sewage from industrial areas of

Sosnowiec, Katowice, Bytom and Czeladź. To the west of the map sheet border, the Rawa River (which is a tributary of the Brynica River) receives all wastewater from the city of Katowice. The eastern part of Katowice is drained by the Bolina River. Its waters are contaminated by sewage discharges from Mysłowice and the KWK Wieczorek coal mine.

Biała Przemsza River and its catchment. The Biała Przemsza River flows through the south-eastern part of the map area, where it is recharged by streams carrying drainage water from the Maczki-Bór sand mine. The Biała Przemsza River valley is natural, but the chemical composition of its alluvial sediments is strongly transformed by anthropogenic factors.

In the analysed river section, alluvial sediments of the Biała Przemsza River are contaminated by arsenic (up to 330 mg/kg), cadmium (up to 125 mg/kg), lead (up to 16 600 mg/kg) and zinc (up to 29 000 mg/kg).

These elements are derived from the sewage discharges of the ZGH Bolesław mine and smelting company as well as mine water from the Olkusz and Pomorzany Zn-Pb ore mines, located beyond the eastern boundary of the map sheet (Olkusz and Bukowno communes). Sewage is discharged into the Biała Przemsza River by the Roznos Canal and Biała and Sztoła rivers (Labus, 1999). Aqueous sediments of the Biała Przemsza River are also enriched in calcium, magnesium, iron and sulphur.

Contamination of sediments by chromium, whose content values locally reach 470 mg/kg, comes from the Szczakowa tannery wastewater discharges to the Kozi Bród Stream (a tributary of the Biała Przemsza River).

Aqueous sediments of watercourses located near the mining waste dump in the central part of the Maczki-Bór excavation are enriched in silver, aluminium, barium, chromium, copper, manganese, nickel, lead and strontium. Mercury concentrations (up to 0.92 mg/kg) are probably related to the leachates from the landfill located at the Maczki-Bór open pit.

Bobrek Stream and its catchment. The springs of the Bobrek Stream are situated in Groniec, in the neighbouring Strzemieszyce Map Sheet area. Much of the pollution in aqueous sediments (enrichment in silver, barium, chromium, mercury and copper) comes from that region.

In the upstream area, the stream is recharged by the canal flowing from the Przyjaźń coking plant, and by numerous drainage ditches. The upstream section of the Bobrek Stream drains the area covered by peat and mud-clay soils of high sorption potential. Alluvial sediments of the stream and its tributaries in this region are enriched in aluminium, arsenic, cadmium, chromium, mercury, iron, manganese, strontium, vanadium and zinc. They also contain high contents of barium (500–1000 mg/kg). The metals originate from wastewater discharges of the Groniec terminals of the special railway transporting iron ore to ArcelorMittal steelworks. Sewage from iron ore crushing plant (located within the rail terminals) is also the source of barium that originates from barite used formerly for mechanical enrichment of ore. Aqueous sediments of the Bobrek Stream, downstream of the confluence with the Rakówka Stream, contain silver (5-40 mg/kg) derived from sewage discharge of the Saint–Gobain Glass company, using silver compounds at the manufacture of mirrors.

Aqueous sediments of the right-bank tributaries of the Bobrek Stream (Rów Mortimerowski Stream and unnamed watercourses draining the Mikrohuta steelworks area, facilities of the abandoned KWK Porąbka-Klimontów coal mine, the Enmech company premises and hazardous waste landfills of the Silma company) are heavily contaminated. The highest concentrations of a number of elements were recorded in aqueous sediments of the unnamed watercourse (recharging the Rów Mortimerowski Stream in its upper section) and some small ponds in its upstream area, polluted by sewage from the Silma Electric Motors Company and by leachates from hazardous waste landfill. These sediments are enriched in silver (up to 3 mg/kg), aluminium (>0.80%), arsenic (20–40 mg/kg), barium (>250 mg/kg), cadmium (10–20 mg/kg), chromium (up to 2230 mg/kg), copper (up to 950 mg/kg), mercury (up to 4.60 mg/kg), nickel (up to 355 mg/kg), lead (>250 mg/kg), phosphorus (up to 0.920%), sulphur (up to 3.902 mg/kg), strontium (150-300 mg/kg), vanadium (20-30 mg/kg) and zinc (up to 40 200 mg/kg).

Aqueous sediments of the downstream part of the Rów Mortimerowski Stream catchment contain high amounts of cobalt (200-300 mg/kg) and manganese (up to 18 800 mg/kg).

High contents of many elements were noted in aqueous sediments of watercourses draining the north-eastern part of the map sheet area and small stagnant water reservoirs. They are contaminated by wastewater discharges from the Mikrohuta steelworks, producing a variety of steel products, and from the ATS Autoterminal Śląsk Logistic warehouse and transportation company. These sediments show particularly high concentrations of cobalt (40-80 mg/kg), chromium (100-200 mg/kg), copper (up to 200 mg/kg), manganese (10 000-30 000 mg/kg), nickel (>1000 mg/kg) and vanadium (40-80 mg/kg).

SURFACE WATER

Czarna Przemsza River and its catchment. Most of the water in the Czarna Przemsza River catchment is slightly alkaline (median pH 7.6). Variability of pH is within the range of 7.0–8.5 (Table 5). Electric conductivity values are very much diversified within this area. In the section from the Pogoria River mouth to the Brynica River mouth, the Czarna Przemsza River water is slightly mineralized with EC values 0.50–0.70 mS/cm.

Enrichment in many elements in the Czarna Przemsza River water occur downstream of the confluences of its tributaries (Pogoria, Brynica and Bolina rivers, and Potok Zagórski Stream) and near sites of discharges of municipal and industrial wastewater. The largest amount of industrial sewage originates from the Będzin thermal-electric power station, smelters (Będzin, Buczek and ArcelorMittal) and from the drainage system of the Sosnowiec KWK coal mine.

Conductivity of the Pogoria River water is 0.89–1.35 mS/cm. It is contaminated by boron, chlorine, lithium, sodium, molybdenum, rubidium, sulphates and strontium. The sources of the water contamination are discharges of mine water from the KWK Paryż coal mine and wastewater from the Huta Bankowa smelter and the Centrum sewage treatment plant in Dąbrowa Górnicza.

The Potok Zagórski Stream water shows EC values between 0.92 and 1.30 mS/cm. It is contaminated by cobalt (median 9.9 μg/dm^3), iron (up to 7.13 mg/dm^3), lithium (median 21 μg/dm^3), nickel (median 17 μg/dm^3), sulphates (median 218 mg/dm^3) and uranium (median 7.47 μg/dm^3) and enriched in boron, chlorine, magnesium, sodium, rubidium, strontium and thallium. This group of elements indicates different pollution sources: one is likely represented by brine discharges, and the other – industrial wastewater discharges from the Będzin smelter and leachates from landfills.

The water of Brynica (EC 1.73–2.03 mS/cm) and Bolina (EC 6.59–8.67 mS/cm) rivers is strongly mineralised. The measured values indicate extreme pollution, that just the electric conductivity value >1 mS/cm itself classifies the water as polluted (Witczak, Adamczyk, 1994). The water of these rivers (as well as the water of the Czarna Przemsza River downstream of their mouths) is contaminated with boron, barium, potassium, lithium, magnesium, sodium, nickel, rubidium, sulphur, antimony and strontium, and enriched in silica. The following values were measured in Bolina River water: boron >600 μg/dm^3, barium >125.00 μg/dm^3, potassium >32.0 mg/dm^3, lithium >170 μg/dm^3, sodium >1000 mg/dm^3, phosphorus >2.00 mg/dm^3 and strontium >3000 μg/dm^3 – the highest values in the whole the Czarna Przemsza River drainage basin. The Brynica River water is additionally enriched in chlorine, cobalt, molybdenum and thallium. The Bolina River water also contain arsenic and phosphorus.

Both the rivers and their tributaries are heavily polluted by discharges of municipal and industrial sewage from Katowice, Siemianowice and Czeladź and saline mine waters from drainage systems of underground coal mines (Murcki, Staszic and Saturn mines).

The highest electrical conductivity value (13.20 mS/cm) was recorded in the water of the tailings pond at the KWK Mysłowice-Wesoła coal mine (Hubertus IV pond) in the Brynica River drainage basin. High concentrations of arsenic (up to 19 μg/dm^3), barium (up to 435.30 μg/dm^3), chlorine (>2500 mg/dm^3), potassium (>32.0 mg/dm^3), lithium (>290 μg/dm^3), sodium (up to 2260.0 mg/dm^3) and strontium (up to 6300,0 μg/dm^3) were observed there.

Biała Przemsza River and its catchment. The water of the Biała Przemsza River catchment is characterized by pH of 7.1–8.2 and EC ranging from 0.64 to 1.40 mS/cm (Table 5). The Biała Przemsza River water is slightly mineralised (EC 0.64–0.67 mS/cm) and contain high amounts of arsenic, cadmium, lead, zinc, molybdenum, antimony and, to a lesser extent, sulphates and silica. Water enrichment in these elements occurs throughout the whole course of the Biała Przemsza River, downstream from sewage discharge point of the ZGH Bolesław zinc smelter and Zn–Pb mines of the Olkusz region. A serious hazard is thallium concentration (>17 μg/dm^3) originating from the same pollution sources. Surface water of the Silesia-Cracow region is commonly enriched in thallium, with its content varying from 0.16 to 3.24 μg/dm^3 (Paulo *et al.*, 2002), while the geochemical background of the surface water in Poland is 0.006 μg/dm^3(Salminen, ed., 2005). Thallium and many of its compounds, especially sulphates, are considered as very toxic substances, whose concentrations in the environment are particularly hazardous to organisms.

The water of unnamed watercourses, draining the area of mine tailings dumps stored in the Maczki-Bór mine working, are contaminated by boron, barium, cobalt, chlorine, iron, magnesium, manganese, lithium, nickel and sodium. Particularly high concentrations were measured for barium (200-300 $\mu g/dm^3$), cobalt (15-60 $\mu g/dm^3$), nickel (10-40 $\mu g/dm^3$), iron (1-3 mg/dm^3) and lithium (5-16 $\mu g/dm^3$). The contamination is related to drainage of the dump site where are dumped coal processing wastes, slag, brown coal fly-ashes, calcium-based flue gas waste, ash-slag mixture of furnace waste and crushed rocks (CTL Maczki-Bór..., 2008).

Bobrek Stream and its catchment. Water acidity of the stream and its tributaries is 6.3–to 8.5 (Table 5). The pH values measured in the water of the streams flowing across the area of mine waste dumps of the KWK Kazimierz-Juliusz coal mine and in the Porąbka district are >8. Electric conductivity of most water in the drainage basin reaches 2 mS/cm (maximum 6.40 mS/cm). The water of two tailings ponds of the KWK Kazimierz-Juliusz coal mine are characterized by EC values >5 mS/cm.

The water of the Rów Mortimerowski Stream and the Bobrek Stream receive saline mine waters from the KWK Porąbka-Klimontów and KWK Kazimierz-Juliusz coal mines. They are the sources of contamination by boron (300-3519 $\mu g/dm^3$), chlorine (160-5200 mg/dm^3), potassium (20-70 mg/dm^3), lithium (50-420 $\mu g/dm^3$), molybdenum (8-10 $\mu g/dm^3$), sodium (150-1080 $\mu g/dm^3$), rubidium (30-876,2 $\mu g/dm^3$), sulphates (200-1758 mg/dm^3), strontium (500-1000 $\mu g/dm^3$) and thallium (0.50-1.90 $\mu g/dm^3$). Some sections of the stream have been walled with coal processing wastes (Skarżyńska *et al.*, 1988), which may be an additional source of water pollution.

The water of right-bank tributaries of the Bobrek Stream is contaminated by sewage from the Mikrohuta steelworks and the Enmech plants, and by the leachates from the hazardous waste landfill near the Silma Company. They contain high concentrations of: arsenic up to 14 $\mu g/dm^3$, barium up to 350 $\mu g/dm^3$, copper up to 13.9 $\mu g/dm^3$, iron up to 14.40 mg/dm^3, manganese up to 3200 $\mu g/dm^3$, molybdenum up to 13.31 $\mu g/dm^3$, phosphorus up to 4.10 mg/dm^3, antimony up to 3.25 $\mu g/dm^3$, cobalt 5-50 $\mu g/dm^3$ and nickel from several to 197 $\mu g/dm^3$.

CONCLUSIONS

1. Chemical composition of soils' parent rocks finds its reflection in geochemistry. The soils formed on Pleistocene glaciofluvial deposits contain small contents of aluminium, barium, calcium, cobalt, chromium, iron, magnesium, manganese, nickel, phosphorus, strontium, titanium and vanadium. It refers to both topsoil (0.0–0.3 m) and subsoil (0.8–1.0 m). The soils that evolved from the Triassic carbonates are conspicuous by increased contents of calcium, magnesium and manganese and are enriched in most of the analyzed elements. The soils that developed from the outcrops of Carboniferous rocks are enriched in aluminium, barium, cobalt, chromium, iron and nickel.

2. In the areas of Triassic Zn–Pb ore-bearing carbonates occurrence and their historical exploitation, the soils are contaminated by cadmium, lead and zinc. Metals are concentrated mainly in the topsoil. In the subsoil a reduction in the areal extent of the anomalies with a simultaneous increase in their intensity are observed.

3. The acidity of the soils is variable and largely constrained by the land use. Soils of industrial and urban areas are usually alkaline or, rarely, neutral, whereas forest soils are acidic.

4. Anthropogenic sources of environmental pollution are: historical mining and processing of Zn–Pb ores, hard coal mining, smelting of iron and non-ferrous metals, chemical and metal industries, activities of workshops and scrap depots, large-scale combustion of coal in heat and power plants and the impact of old mining waste heaps.

5. Contamination of aqueous sediments and surface waters, mainly of anthropogenic origin, is related to discharge of mine water (from active and closed coal mines) and industrial and municipal sewage, as well as drainage of mine waste dumps.

6. Aqueous sediments are polluted mainly by metals derived from contemporary and historical smelting (chromium, zinc, cadmium, cobalt, copper, nickel, lead, mercury, silver and iron) and activities of metallurgical plants.

7. The analysed surface water is characterized by high variability in terms of the content of chemical elements and the values of acidity and electrical conductivity. The water is mainly slightly alkaline. High salinity observed in most watercourses is associated with discharges of mineralised mine water. The water discharged by coal mines causes pollution of watercourses by boron, chlorine, potassium, lithium, molybdenum, sodium, strontium, sulphate, rubidium, thallium and antimony.

8. The water of streams draining the areas of waste dumps is enriched in arsenic, barium, copper, iron, manganese, molybdenum, phosphorus and antimony.

REFERENCES

BIERNAT S., 1970 – Objaśnienia do Szczegółowej Mapy Geologicznej Polski 1:50 000, ark. Katowice. Wyd. Geol., Warszawa.

BIERNAT S., KRYSOWSKA M., 1956 – Szczegółowa Mapa Geologiczna Polski 1:50 000, ark. Katowice. Wyd. Geol., Warszawa.

BUKOWY S., 1974 – Monoklina śląsko-krakowska i zapadlisko górnośląskie. *W*: Budowa geologiczna Polski. T. 4, Tektonika. Cz. I: Niż Polski: 213–232. Wyd. Geol., Warszawa.

CHWASTEK J., JANUSZ W., MIKOŁAJCZAK J., 1990 – Deformacje powierzchni terenu spowodowane działalnością górniczą. *W*: Zasady ochrony i kształtowania środowiska przyrodniczego na obszarach eksploatacji złóż kopalin. (red. S. Kozłowski): 145–157. Wyd. SGGW-AR, Warszawa.

CTL Maczki-Bór, 2008. http://www.ctl.pl/ctlmaczkibor/

DŁUGOBORSKI W. (RED.), 1976 – Dąbrowa Górnicza. Zarys rozwoju miasta. Wyd. Śląsk. Katowice.

DOKTOROWICZ-HREBNICKI S., 1935 – Arkusz Grodziec. Objaśnienia do mapy geologicznej Górnośląskiego Zagłębia Węglowego 1:25 000. Państw. Inst. Geol., Warszawa.

GÓRECKA E., 1993 – Geological setting of the Silesian-Cracow Zn–Pb deposits. *Kwart. Geol*., **37**, 2: 127–145.

GÓRECKA E., 1996 – Mineral sequence development in the Zn–Pb deposits of the Silesian-Cracow area, Poland. *Pr. Państw. Inst. Geol*., **154**: 26–36.

HISTORIA miasta Sosnowiec, 2008. http://um.sosnowiec.pl/

JOCHEMCZYK L., OLSZEWSKA K., 2002 – Mapa geośrodowiskowa Polski w skali 1:50 000, ark. Katowice. Państw. Inst. Geol. Warszawa.

KABATA-PENDIAS A., PIOTROWSKA M., MOTOWICKA-TERELAK T., MALISZEWSKA-KORDYBACH B., FILIPIAK K., KRAKOWIAK A., PIETRUCH C., 1995 – Podstawy oceny chemicznego zanieczyszczenia gleb. Metale ciężkie, siarka i WWA. Biblioteka Monitoringu Środowiska, Warszawa.

KATOWICKI Holding Węglowy S.A., 2008. http://www.khw.pl/

KLECZKOWSKI A. S., 1990 – Mapa obszarów Głównych Zbiorników Wód Podziemnych (GZWP) w Polsce, wymagających szczególnej ochrony 1:500 000. AGH, Kraków.

KONDRACKI J., 2000 – Geografia regionalna Polski. Wyd. Nauk. PWN, Warszawa.

KOWALSKA Z., 1997 – Objaśnienia do mapy geologiczno-gospodarczej Polski 1:50 000, ark. Katowice. Państw. Inst. Geol., Warszawa.

KWK Kazimierz-Juliusz, 2010. http://www.kazimierzjuliusz.pl/

LABUS K., 1999 – Stopień zanieczyszczenia i identyfikacja ognisk zanieczyszczeń kadmem, ołowiem i cynkiem wód powierzchniowych i podziemnych zlewni Białej Przemszy. Wyd. Inst. Geol. Sur. i Ener. PAN, Kraków.

LIS J., PASIECZNA A., 1995a – Atlas geochemiczny Polski 1:2 500 000. Państw. Inst. Geol., Warszawa.

LIS J., PASIECZNA A., 1995b – Atlas geochemiczny Górnego Śląska 1: 200 000. Państw. Inst. Geol., Warszawa.

LIS J., PASIECZNA A., 1997 – Anomalie geochemiczne Pb-Zn-Cd w glebach na Górnym Śląsku. *Prz. Geol.*, ***45***, 2: 182–189.

LIS J., PASIECZNA A., 1999 – Szczegółowa mapa geochemiczna Górnego Śląska 1: 25 000. Promocyjny arkusz Sławków. Państw. Inst. Geol., Warszawa.

OCENA jakości wód powierzchniowych województwa śląskiego w 2006 r., 2007. WIOŚ Katowice. http://www.katowice.pios.gov.pl/

PAULO A., LIS J., PASIECZNA A., 2002 – Tal pod koniec XX wieku. *Prz. Geol.*, ***50***, 5: 403–407.

PROGRAM ochrony środowiska dla miasta Sosnowca, 2003a. http://www.sosnowiec.pl/

PROGRAM Ochrony środowiska dla miasta Dąbrowa Górnicza wraz z Planem gospodarki odpadami, 2003b. http://www.dabrowa-gornicza.pl/

PROGRAM ochrony środowiska dla miasta Będzina na lata 2004-2015, 2004. http://www.bendzin.bip.info.pl/

PRZEMYSŁ - Dąbrowa Górnicza, 2008. http://dabrowa.pl/

PRZENIOSŁO S., red., 2005 – Bilans zasobów kopalin i wód podziemnych w Polsce, 2004. Państw. Inst. Geol., Warszawa.

PRZENIOSŁO S., red., 1997 – Bilans zasobów kopalin i wód podziemnych w Polsce, 1996. Państw. Inst. Geol., Warszawa.

PRZENIOSŁO S., red., 2005 – Bilans zasobów kopalin i wód podziemnych w Polsce, 2004. Państw. Inst. Geol., Warszawa.

PRZENIOSŁO S., red., 2007 – Bilans zasobów kopalin i wód podziemnych w Polsce, 2006. Państw. Inst. Geol., Warszawa.

ROZPORZĄDZENIE MINISTRA ŚRODOWISKA z dnia 9 września 2002 r. w sprawie standardów jakości gleby oraz standardów jakości ziemi. DzU Nr 165, poz. 1359.

ROZPORZĄDZENIE MINISTRA ŚRODOWISKA z dnia 11 lutego 2004 r. w sprawie klasyfikacji dla prezentowania stanu wód powierzchniowych i podziemnych, sposobu prowadzenia monitoringu oraz interpretacji wyników i prezentacji stanu tych wód. DzU Nr 32, poz. 284.

RZEPECKI J., SUCHANECKI P., 1995 – Mapa sozologiczna 1:50 000, ark. Katowice. Przeds. Geopol, Poznań.

RÓŻKOWSKA A., PTAK B., 1995a – Bar w węglach kamiennych Górnego Śląska. *Prz. Geol.,* **43**, 3: 223–226.

RÓŻKOWSKA A., PTAK B., 1995b – Atlas geochemiczny złóż węgla kamiennego Górnośląskiego Zagłębia Węglowego. Państw. Inst. Geol., Warszawa.

RÓŻKOWSKI A., SIEMIŃSKI A., 1995 – Mapa ognisk zanieczyszczeń wód podziemnych Górnośląskiego Zagłębia Węglowego i jego obrzeżenia w skali 1:100 000. Państw. Inst. Geol., Warszawa.

SALMINEN r. (red.), 2005 – Geochemical Atlas of Europe. Part 1. Geological Survey of Finland. Espoo.

SKARŻYŃSKA K. M., BURDA H., KLEPACZ J., 1988 – Obiekty budownictwa wodnego z nieprzepuszczalnych odpadów kopalni węgla kamiennego. *Gosp. Wod.*, **3**: 68–71.

SOSNOWIEC ONLINE – Radocha, 2008. http://www.sosnowiec.info.pl/

SZUWARZYŃSKI M. 1996 – Ore bodies in the Silesian-Cracow Zn–Pb ore district, Poland. *Pr. Państw. Inst. Geol.*, **154**: 9–24.

VADEMECUM 08/09, 2009 – Górnictwo i geologia, energetyka, hutnictwo 17. Bibl. Szkoły Eksploatacji Podziemnej. Wyd. IGSMIE PAN, Kraków.

WILK Z., 1990 – Przeobrażenia stosunków wodnych. *W*: Zasady ochrony i kształtowania środowiska przyrodniczego na obszarach eksploatacji złóż kopalin. (red. S. Kozłowski): 123–133 Wyd. SGGW-AR, Warszawa.

WITCZAK S., ADAMCZYK A., 1994 – Katalog wybranych fizycznych i chemicznych wskaźników zanieczyszczeń wód podziemnych i metod ich oznaczania. T. 1. Biblioteka Monitoringu Środowiska, Warszawa.

ZAKŁADY Górniczo-Hutnicze Bolesław, 2010. http://zgh.pl/

ZIELIŃSKI T., LEWANDOWSKI J., 1990 – Analiza sedymentologiczna osadów kopalnej doliny Białej Przemszy na Wyżynie Śląskiej. *Biul. Państw. Inst. Geol*., **364**: 127–151.